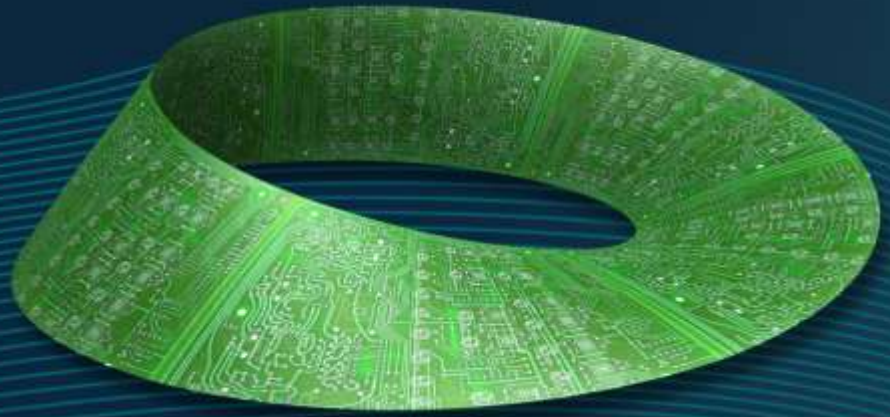


Flexible Hybrid Electronics: Supporting The DOD Mission

Eric Forsythe, PhD
(Program Manager, Army Research Lab)
Ben Leever, PhD
(Gov't CTO, Air Force Research Lab)
Mark Gordon (OSD Liaison)
Charlotte Chumack (AFRL Contracting)
Tracy Frost Dir, OSD MIBP
Melissa Grupen-Shemansky
(SEMI-FlexTech Alliance CTO)
Michael Ciesinski
(SEMI-FlexTech Alliance President)

Malcolm Thompson, PhD
(NextFlex Executive Director)
Jason Marsh
(NextFlex Director for Technology)
Paul Semenza
(NextFlex Director for Commercialization)
Dennis Mahony
(NextFlex Director for Operations)

Harvey Tsang, PhD (ARL, 3D Hybrid)
Romeo del Rosario, PhD (ARL BC)

Flexible Hybrid Electronics Mission

IMPACT

- Novel Form Factors
- Light-weight, rugged
- Low-cost approaches through new manufacturing
- Enabling novel-sensing capabilities

NextFlex Supporting DoD Missions









DOD EXAMPLES

Human Monitoring Systems

Asset Monitoring Systems

Integrated Array Antenna Systems

Soft Robotics

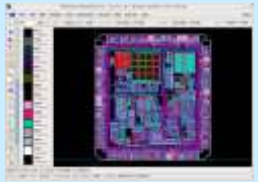
Critical Materials in FHE technology

- Introduce Flexible Hybrid Electronics in context with Electronics Packaging
- NextFlex: the manufacturing institute is MRL 4-7 (TRL 5-8). Depends on demonstrated materials
- NextFlex is enabling a materials database for conductinve materials, active electronic materials, dielectrics and semiconductors
- Important to put critical material needs in context with the manufacturing processes
- ARL is managing other related programs in lower TRL

Broad Electronic Industry Categories

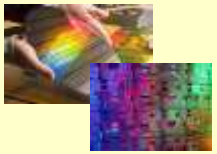
Software Design Tools

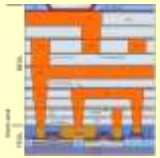
Electronic Design Automation EDA (Process Design Kit)



Wafer Fab (foundries)

FEOL (front-end-of-line)
BEOL (back-end-of-line)





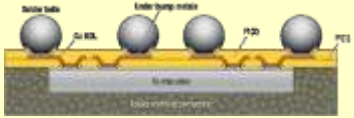
Traditional Silicon ICs, GaAs, GaN, SiC etc

Longer-term RD (Low TRL)

2D Mat'l

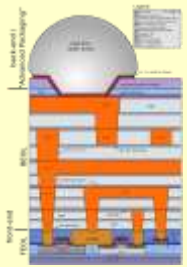
Wafer Fab AND OSATs

MEOL (Middle-end-of-line)



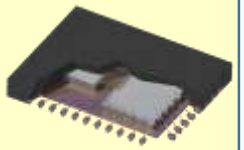
Fan-Out Wafer Level Packaging

Advanced Packaging



Outsource Assembly and Test (OSAT)

System in Package (SiP)
System on Chip

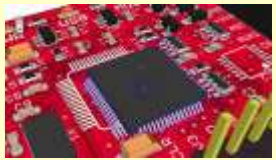


3D Die stacking
Component/Devices

Electronic Manf Service (EMS):

Flexible Hybrid Electronics

Printed Circuit Board Layouts, PDKs
Traditional Multi-layer thru-vias
SENSORS not traditionally in EMS



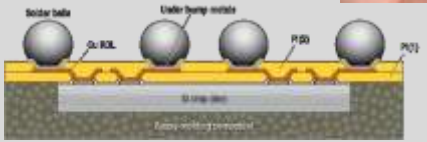
What is Flexible Hybrid Electronics?

Man'f Challenges: Die Assembly conductors, adhesives, dielectrics, substrates, sensors, power
Metal interfaces, dynamic mechanical properties, processing conditions, yield, cost

Electronics Manufacturing Services

Thin Si CMOS

POWER



Manufacturing Convergence for Application Spaces

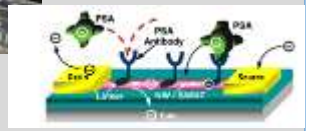
Human Monitoring Systems

Asset Monitoring Systems

Integrated Array Antenna Systems

Soft Robotics

Low-temperature Manufacturing Processes High-speed automation Printed Sensors



NextFlex Program Thrusts

Catalyzing a robust and innovative manufacturing ecosystem at the intersection of the electronics and high performance printing industries.

1. **Institute Acquisition Process:** Develop a sustainable FHE manufacturing ecosystem through Industrial-led Projects – risk reduction for manufacturing gaps. Concept paper phase: Institute can propose re-teaming to optimize DOD investments.
2. **Pilot-scale manufacturing facility Knowledge Sustainment** San Jose, CA for Low-volume FHE integration to support small business and DOD
3. **Education and Work Force Development** from K-12 outreach through workforce development and re-training to create a sustainable manufacturing workforce
4. **Enable collaborative Ecosystem** between industry, government and academics to focus the FHE ecosystem
5. **Rapid acquisition vehicle** for agency FHE funding
    1. Leverage NextFlex review structure
    2. Agencies control their own funding, final funding authority& management
    3. Rapid project award through existing Open Project Call process, Obligation/Expenditures

NextFlex Institute Integrated Strategy:
Project collaboration in Wearables and Health-care

Health Care Sensors
in unique places

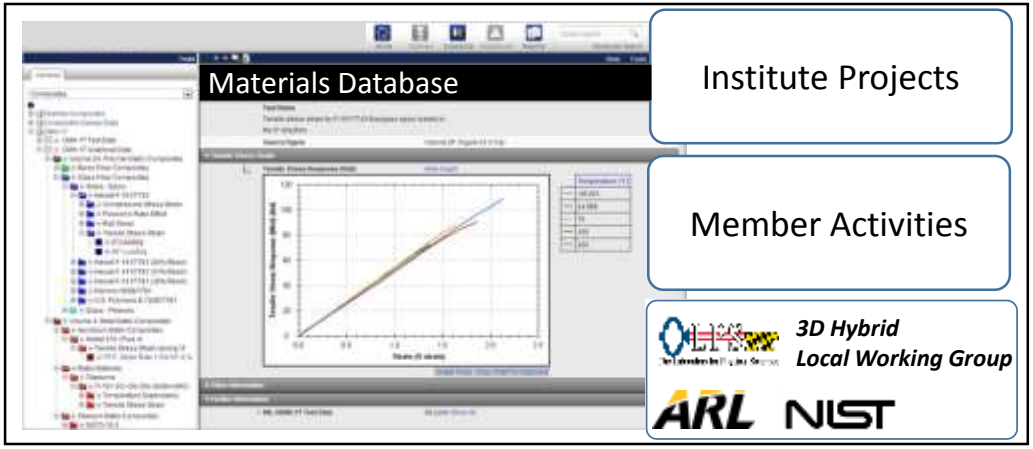
NEW YORK STATE

Supporting DOD Missions

Academic engaged training
students through reliability

- NextFlex's 72 Members across the US currently leverage 26 projects totaling $45M
- Enabling New FHE Manufacturing tools with US-based tool company (*Universal Instruments*)
- Enabling US FHE Manufacturing with DoD Trusted Supplier for electronics packaging and assembly (*i3 electronics*)
- Creating Manufacturing for Health Care Products supporting our DoD Mission (*General Electric*)
- Pilotline development impacting deliverable specs (reducing project risk)
- Capture long term knowledge: Tool integration at pilotline and NYS node
- Capture DOD engagement: through "Agency projects"

NextFlex Pilot scale manufacturing and knowledge integration:
Institute Technical Capabilities



- NextFlex's 72 Members across the US currently leverage 26 projects totaling $45M
- <u>Knowledge Capture and information Sustainment</u>:
  - Materials Database
- <u>Knowledge Capture and Process Sustainment</u>:
  - Pilotline integrated tool and processes
- Manufacturing process projects will capture information in a materials database that members utilize
- Integrate the NIST Materials Genome Initiative – details are in discussion
- Discussions ARL with NIST to leverage Brookhaven Beamline for materials characterization
- Institute Projects are developing next generation FHE tools for installation in Pilotline
- Institute Manufacturing process projects utilize tools to be available at institute

Education and WFD: *Example*

Leveraging Agency Funding and creating an FHE trained workforce

BMNT H4D

- Team Aqualink focused on helping develop an underwater sensor for Navy special operations divers.
- With the help of NextFlex, and one of our member companies who served as an industry mentor, the student team built a functioning prototype.

"Having an organization like NextFlex to partner with - an entity who understood the commercial landscape, with a solid grasp of government ecosystems, and a vision for how those two should interact together was invaluable. NextFlex provided an incredible amount of help, from mentoring and coaching the team through business cycles and DoD procurement processes, to facilitating key partnerships between academic, commercial, and government agencies to produce an exponentially better product. Without this relationship we would have spent three to four times the energy and effort, and potentially failed to meet our goals."

Dave Ahern, Student, Team Aqualink, H4D Course at Stanford University, June 2016

NextFlex Member Collaboration: *Workshops*

Workshop 17 MAR 2017:
Technical Leaders in the field:

- AFRL Keynote (ST) from the RH
- CTO GE Health Care Business Unit
- ASU Prof Leading expert in Biomakers

Telemedicine and other digital services will be favored by providers under value-based payment if, and only if, they:

- ❑ Reduce costs to providers (and not merely improve quality) and have data to support it

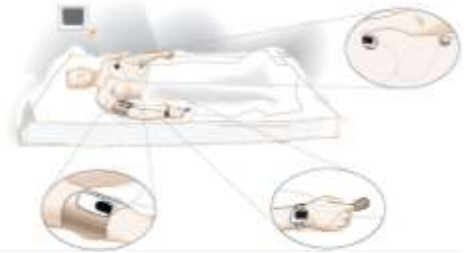
Consumer wearables and other mobile products will be favored if, and only if, they:

- ❑ Increase adherence and change behavior in ways that support cost reduction initiatives by providers, and have data to support it

Today's Medical Environment

Flexible Hybrid Electronics Manufacturing

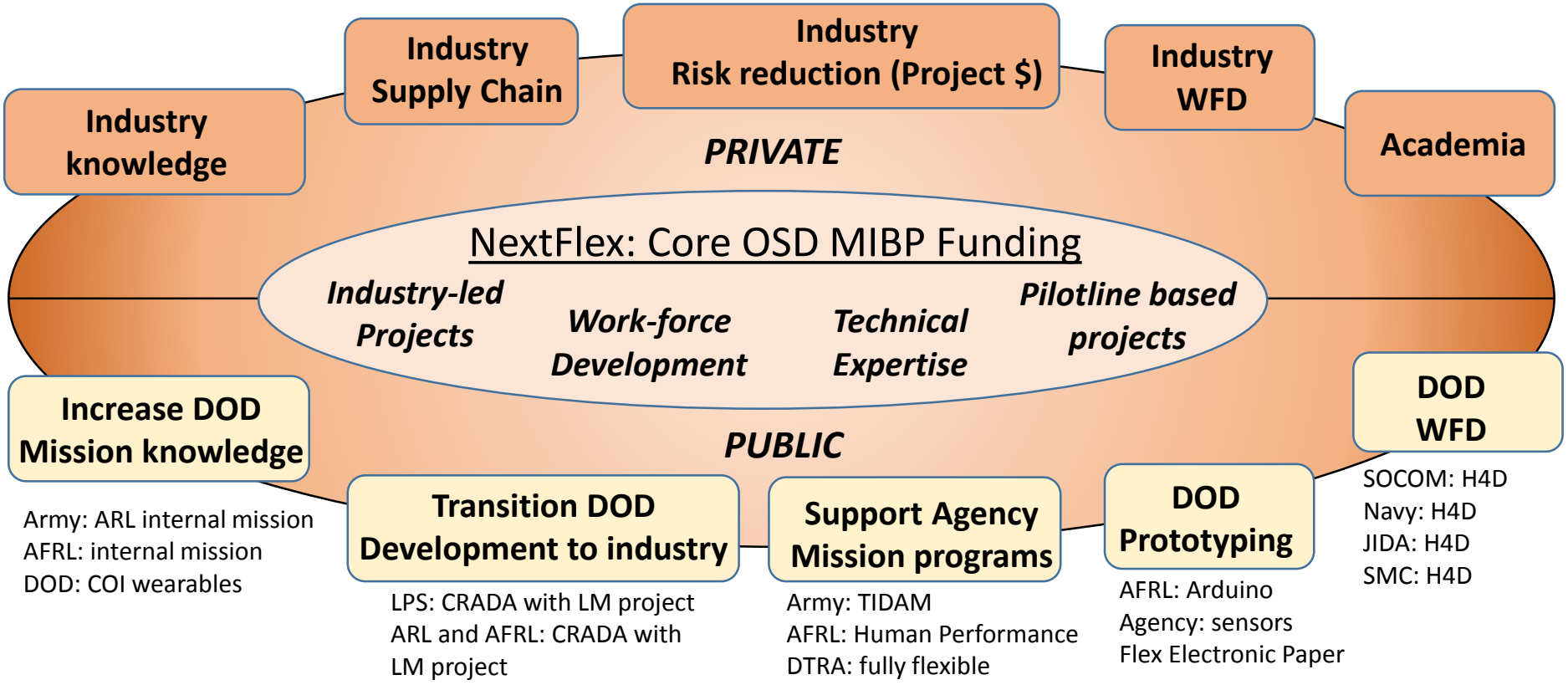
Tomorrow's Medical Environment thru FHE manufacturing innovation



Vision Presented by the CTO GE Healthcare business unit: March 2017 NextFlex Workshop

Technology Transition: *Agency funding*

Supporting 14 Different DOD-OGA Transition Programs



Army: ARL internal mission
AFRL: internal mission
DOD: COI wearables

LPS: CRADA with LM project
ARL and AFRL: CRADA with LM project

Army: TIDAM
AFRL: Human Performance
DTRA: fully flexible

AFRL: Arduino
Agency: sensors
Flex Electronic Paper

SOCOM: H4D
Navy: H4D
JIDA: H4D
SMC: H4D

FlexTech R&D Programs

Intersecting DoD Technology requirements and Industry Manufacturing direction

Intersecting ARL objectives and Industry R&D

Intersecting AFRL (RX, RH, RY, 711th) objectives and Industry R&D

Flexible Hybrid Electronics Manufacturing

- Man'f Gaps
- Public-private partnership
- 41+ members
- 150+ Gov't SMEs

Flexible Hybrid Electronics Technology Gaps for Broad Applications

- Lightweight, low power, conformable electronics
- CMOS Integration
- Radio and communications
- Sensing, warnings, wearable displays

Flexible, Wearable Human Performance Monitoring Electronics

- Pilot
- First Responder
- Maintainer

semi | FlexTech

Battery Capacity Needs by Application

IoT, MEMS, CMOS memories, Medical implantable	Smart cards, Skin patch, RFID	Wearables, E-textile, Medical device	Smartphone, Tablet, Power tool, Toy	Transport	Large-scale energy storage
Capacity range →					
1 mAh	10 mAh	100 mAh	1 Ah	100 Ah	> 1 kAh
Important features					
• Rechargeable • Small footprint, many micro-batteries • Long life time • Rapid discharge • Tend to incorporate with energy harvesting	• Can be both disposable and rechargeable • Laminar and thin, some with special form factor • Relatively low power • Cost sensitive	• High energy density for small volume • Long working hours • Flexible, stretchable or thin, some with special form factor	• Light-weight and small volume • Long working hours • Some with special form factors • High power	• Safe • Reliable • High power • High capacity	• Cost advantage • Long life time • Reliable • High capacity
					
Technology Status					
Small volume production	Available, mostly customized	Prototypes available	Research to prototype	Research	Very early stage

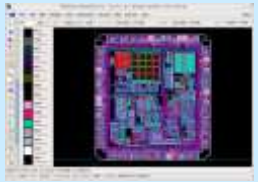
Source: IDTechEx

Present FlexTech Project Efforts

3D and Additive Research in Electronics

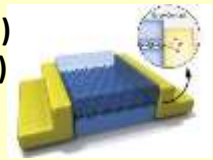
Software Design Tools

Integrating 3D CAD packages and electronics



Wafer Fab (foundries): Printed electronics Active Transistors

FEOL (front-end-of-line)
BEOL (back-end-of-line)

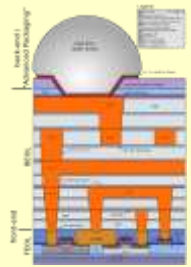


- Printed Electronics
- EU invested heavily in PE
- No significant products after 25yrs
- Features sizes 1000x larger than CMOS

Wafer Fab AND OSATs

MEOL (Middle-end-of-line)

Advanced Packaging



- Features sizes in Wafer level processing <<< printing resolutions
- Conductor performance poor

Outsource Assembly and Test (OSAT)

OPTOMEC

3D Additive Die interconnects

Electronic Manf Service (EMS):

3D Hybrid Electronics Space

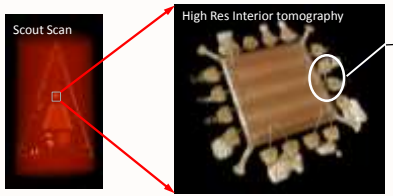
AFRL printing Antennas (mesoscribe)

Voxel8
ARL

3D and Additive Research in Electronics

ARL 3D Hybrid Electronics Fabrication Capability

nScrypt with FlexTech Alliance

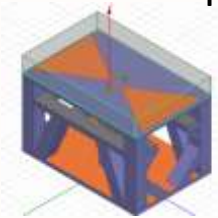


Ziess xradia CT Microscope

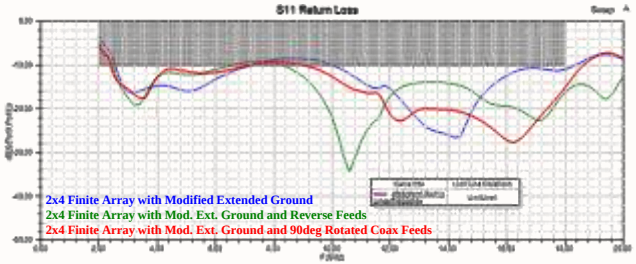
Standard wire-bonds

Novel printed wire-bonds

ARL printed phase array antenna and performance data



X-ray CT scan structure



2-18Ghz PAA

Future Work

NextFlex Leveraging: Transition knowledge FROM NextFlex community for long-term Army Mission

Summary

- Introduce Flexible Hybrid Electronics in context with Electronics Packaging
- NextFlex: the manufacturing institute is MRL 4-7 (TRL 5-8). Depends on demonstrated materials
- NextFlex is enabling a materials database for conductinve materials, active electronic materials, dielectrics and semiconductors
- Important to put critical material needs in context with the manufacturing processes
- ARL is managing other related programs in lower TRL

Institute Membership

Corporate

Tier 1

Tier 2

Tier 3

Academic / Non-Profit

- ***Founding Member, no members have departed to date***

Observer

Honorary

GOVERNMENT PARTNERS